Screening of Soil Amendment as a Potential Urban Garden Soil Lead Remediation Treatment

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Abstract

Lead contamination in urban soils is a widespread problem caused by industry, leaded paint, and lead additives in gasoline up until the 1970’s. Methods are now being developed to treat the lead on site so that it no longer poses a health threat. One method that has proven effective is phosphate fertilizers, although results and rate requirements differ for each soil. The objective of this study was to evaluate the effectiveness of a commercial fertilizer-like product in immobilizing lead in contaminated soil intended for an urban garden. To do this, treatment was applied and allowed to incubate and was then analyzed for soil solution lead and relative bioavailability. While soil solution lead was significantly reduced, relative bioavailability was relatively unaffected. These results suggest the treatment would be effective for reducing the amount of lead that would be available to plants, but would not be effective in reducing exposure through direct soil ingestion.

Introduction

Although Pb is a naturally occurring element in soil, Pb contamination is common, especially in urban soils (Mielke, 2008). Sources include industry, Pb based paint used up until 1978, and most significantly, Pb additives used in gasoline (Mielke, 2008; Mielke 2011). Although the EPA standard for soil Pb is 400 ppm, there are cases where over half of urban soil exceed this limit, some reaching over 50,000 ppm (USEPA, 2001; Mielke, 2008).

Exposure Pathways

Most exposure to Pb is through some form of contact with soil particles, and blood Pb has been shown to increase significantly with soil Pb levels in the surrounding area (Zahran, 2009). Pb from the soil is absorbed through inhalation of dust particles, ingestion of soil and dust, and consumption of food and water from contaminated areas.

To study atmospheric Pb dynamics, Laidlaw (2012) measured atmospheric Pb over time and found that there is a strong correlation between atmospheric Pb and soil Pb. Atmospheric Pb showed cyclical patterns peaking in summer and autumn months and contracting in the winter, suggesting greatest exposure risk during the season people spend the most time outdoors. It was also three times higher on workdays than on weekends and federal holidays suggesting anthropogenic turbulence contributes to lead aerosols (Laidlaw, 2012) and therefore exposure risk through soil inhalation and ingestion.

Soil ingestion is particularly relevant for children, who spend a lot of time on floors and outside in direct contact with the soil. One study that attempted to assess childrens risk of Pb exposure on playgrounds measured Pb dust on play surfaces compared to soil Pb and found that the two strongly correlate (Mielke, 2007). Using the observed relationship between the two, to stay below the 40 ug/ft^2 surface wipe standard recommended by the EPA, soil lead would have to stay below 7.2 ppm, suggesting that even soils below screening levels can cause surface Pb that exceeds wipe standards (USEPA, 2001;

Mielke, 2007). Children are not only disproportionally exposed through soil and dust, but also direct ingestion of paint chips and ingestion of indoor dust from contaminated paint.

Health effects

Pb tends to attack the brain, and children exposed to Pb prenatally have measurably lower IQ scores than those who were not exposed, although the relationship was only found to be significant for blood Pb scores during the third trimester, particularly week 28 of pregnancy (Schnaas, 2006). In a study of urban children exposed to relatively high amounts of Pb, blood Pb levels were significantly negatively correlated with student test scores, so much as to be a better predictor of test scores than both poverty and class size (Zahran, 2009). Elevated body Pb burdens were also associated with a higher risk of adjudicated delinquency (Needleman, 2002), suggesting decreased impulse control and in light of the effects on test scores, could be an indirect result of hindered achievement.

Pb can harm more than just cognitive function. In a study by Tsaih (2004), tibia Pb was measured as an indicator of exposure since Pb accumulates in bones over time and a significant relationship was found between tibia Pb and diabetes. This relationship was amplified in those who already had hypertension, and since hypertension is prevalent in America, we could potentially be at increased risk of impaired renal function caused by Pb exposure.

Remediation

When remediating Pb contaminated soil, common practice used to be to remove the soil and replace it with clean soil. This method is very expensive and methods are being developed now to treat the soil on site (in-situ) to either remove the Pb or immobilize it. Soil washing can be an effective way to remove Pb from soil, although it is fairly intensive and highly dependent on soil type (Isoyama, 2007). In this method, water is pumped through the soils with an acid to solubilize the Pb and remove it from soil surfaces. Sandy soils responded well since they allowed the free flow of water through them whereas soils with high amounts of clay inhibited the treatment and did not show as beneficial results (Isoyama, 2007). This type of soil washing can be of concern because the solubilized Pb has the potential to leach into the groundwater and create more problems than were present before.

A more practical solution to Pb contamination is to immobilize the Pb so that it is no longer a health or ecological threat. One study used meat and bone meal combustion residue as a treatment and found that Pb is quickly immobilized into lead pyromorphite and lead carbonate dehydrate, both very stable minerals (Deydier, 2007). Phosphorus treatments have likewise been shown to reduce Pb bioavailability (Hettiarachchi, 2001), although this has the potential to create a water quality problem if phosphorus is leached from the system.

The treatment in this study was a proprietary fertilizer-like product marketed previously as a treatment for Pb based paint and is now being considered as a possible soil amendment.

Materials and Methods

Soil was collected from The Asian Garden, a vacant lot located in Cleveland, OH, by random sampling at a 0 – 10 cm depth and a composite was made from which samples were taken. Soils were oven dried at 60ºC and sieved <2mm. A sample was taken from the composite for the control and the total Pb content was found to be 674 mg/kg, much higher than the 400 mg/kg soil screening level set by the USEPA (USEPA, 2001). The bioaccessible Pb(IVBA), determined by in vitro gastrointestinal extraction (Drexler and Brattin, 2007) at pH 2.5, was 350.5 mg/kg, or 52% of total Pb.

Soil was treated with a commercial fertilizer-like product by adding 6.29 g of amendment to 500 g of soil. The soil mixture was kept moist at 2/3 of saturated capacity and incubated for 6 weeks at 25˚C. It was tested for solution Pb, pH, phosphorus content, and was tested twice for total and in vitro Pb.

After incubation, soils were centrifuged and soil solution was collected. The concentration of cations and anions and pH was determined for collected soil solution. The pH of the soil solution was determined using a glass electrode. Cations were determined by using inductively couple plasma optical emission spectroscopy (ICP) and anions were determined by using ion chromatography.

Total Pb concentration of soil was determined by USEPA method 3051A, a microwave assisted extraction using an aqua regia type solution of HCL and HNO3. The solution was analyzed using inductively couple plasma optical emission spectroscopy (ICP).

A modified version of the Relative Bioaccessible Leaching Procedure was used to determine bioaccessible Pb in the treated soils. A 1:100 soil:solution (0.4M Glycine) maintained at a pH of 2.5 was incubated at 37ºC for 1 hour. Pb was determined using inductively couple plasma optical emission spectroscopy (ICP). The following equation was used to determine the relative bioavailability (RBA):

% RBA = (1.341*[% IVBA]) – 1.607

% IVBA = (IVBA Pb/Total Pb)*100

Soil test P was determined using the Mehlich 3 soil test.

Results and Discussion

Table 1. Summary of selected chemical properties for study soils

	Total Pb	In Vitro Extraction	Relative Bioavailability of Pb (RBA)	Soil solution Pb	Soil test Phosphorus	Soil pH
	mg/kg		%	mg/L	mg/kg	
Control Soil	674	350.5	52	0.04	100	6.95
Treatment test 1	656	328	50			
Treatment test 2	695	325	47			
Treatment Mean	675.5	326.5	48	0.01	205	6.30

Relative bioavailability is a measure of how much Pb will be absorbed into the bloodstream if ingested (Drexler and Brattin, 2007). Direct soil ingestion is a major concern especially for small children since they frequently put their hands/toys in their mouths, and therefore children could be exposed to unsafe levels of Pb if allowed to play on a contaminated site. Soil ingestion through inhalation would also be a concern, because since this plot would be cultivated, plant cover would not always provide a barrier to hold soil in.

The USEPA soil screening level for Pb is 400 mg/kg (USEPA, 2001) and assumes 60% relative bioavailability (USEPA, 1994). This would be equivalent to 240 mg/kg at 100% relative bioavailability which would be considered the threshold for successful Pb treatment. Treatment only reduced relative bioavailability to 48% and at 675.5 mg/kg, is equivalent to 324.24 mg/kg at 100% relative bioavailability. This suggests treatment was not effective at reducing risk through soil ingestion. While this may be the case, it is in contrast to other studies of phosphate treatments in which relative bioavailability was reduced by as much as 38% (Hettiarachchi, 2001). Hettiarachchi (2001) also observed different results based on soil type which could explain the difference with the Asian Garden soil.

Using this plot as a community garden creates an exposure pathway through food. Plants can only uptake Pb that is in soil solution, so exposure risk through the food chain directly relate to soil solution Pb. Treatment reduced soil solution Pb by 75%, thus greatly reducing exposure through food.

Treatment increased the soil phosphorus to 205 mg/ kg, well above the Ohio screening level of 150 mg/kg. While treatment of one plot would not be enough to cause a water quality problem, if this treatment were implemented city wide it could potentially cause eutrophication downstream. Finally, although pH was lowered it was not below pH 5 and therefore should not cause any acidity problems that could hinder plant growth.

Conclusion

The relative bioavailability was not reduced to a level that would be below the USEPA threshold, and therefore this treatment was not effective at reducing exposure due to ingestion. It was effective, however, at reducing exposure through the food chain. With these results, I would say this treatment could be effective for a community garden if children were not allowed to play in it and care was taken not to ingest the soil, although this could be difficult.

One possible explanation as to why this was not highly effective on soil is that the Pb in paint is more soluble and able to react with the treatment and therefore be bound. In soils, Pb may be complexed with different soil particles and therefore unable to react with the treatment. This is supported by the contrasting results between reductions in soil solution Pb and reductions in relative bioavailability. Pb that is already in solution can easily react with the treatment and therefore solution Pb would be expected to decrease. On the other hand, Pb that is not in solution may be bound to soil particles tightly enough to not be available to react with the treatment, but not so strongly bound as to not solubilize when in strong acid. This would mean any lead that solubilized during in vitro treatment would not be affected, as was observed, and the slight reduction in relative bioavailability was probably due to the soil solution Pb being bound by the treatment. This brings up an issue for in-situ soil Pb treatments. To make significant impacts on relative bioavailability Pb must be able to react with the treatment, but any efforts to solubilize the Pb in soil poses a risk to water quality as rain could leach Pb into drinking water and cause a greater problem than was being treated. Consequently, further research must be done to develop methods of increasing reactivity with treatment without creating new threats elsewhere.

Limitations

This study was only a preliminary screening for a proprietary product's potential to immobilize Pb, and significance is limited by the fact only two samples were tested for bioavailability. Although results suggest this is not effective at reducing relative bioavailability, further investigation must be done to determine if that is the case and if so, why.

Works Cited

Deydier, E., Guilet, R., Cren, S., Pereas, V., Mouchet, F., & Gauthier, L. (2007). Evaluation of meat and bone meal combustion residue as lead immobilizing material for in situ remediation of polluted aqueous solutions and soils: "Chemical and ecotoxicological studies". *Journal of Hazardous Materials, 146,* 227-236.

Drexler, J.W. & Brattin, W.J. (2007). An In Vitro Procedure for Estimation of Lead Relative Bioavailability: With Validation. *Human and Ecological Risk Assessment,* 13, 383-401.

Hettiarachchi, G. M., Pierzynski, G. M., & Ransom, M. D. (2001). In situ stabilization of soil lead using phosphorus. *Journal of Environmental Quality, 30 (4),* 1214-1221.

Isoyama, M., Wada, S. I., & Site Remediation Technologies. (2007). Remediation of Pb- contaminated soils by washing with hydrochloric acid and subsequent immobilization with calcite and allophanic soil. *Journal of Hazardous Materials, 143 (*3), 636-642.

Laidlaw, M. A. S., Zahran, S., Mielke, H. W., Taylor, M. P., & Filippelli, G. M. (2012). Re-suspension of lead contaminated urban soil as a dominant source of atmospheric lead in Birmingham, Chicago, Detroit and Pittsburgh, USA. *Atmospheric Environment, 49,* 302-310.

Mielke, H. W., Gonzales, C. R., & Mielke, P. W. (2011). The continuing impact of lead dust on children's blood lead: Comparison of public and private properties in New Orleans. *Environmental Research, 111 (8),* 1164-1172.

Mielke, H., Gonzales, C., Powell, E., & Mielke, P. (2008). Urban soil-lead (Pb) footprint: retrospective comparison of public and private properties in New Orleans. *Environmental Geochemistry and Health, 30(3),* 231-242.

Mielke, H. W., Powell, E. T., Gonzales, C. R., & Mielke, P. W. (2007). Potential lead on play surfaces: Evaluation of the "PLOPS" sampler as a new tool for primary lead prevention. *Environmental Research, 103 (2),* 154-159.

Needleman, H. L., McFarland, C., Ness, R. B., Fienberg, S. E., & Tobin, M. J. (2002). Bone lead levels in adjudicated delinquents:A case control study. *Neurotoxicology and Teratology, 24(6),* 711-717.

Schnaas, L., Rothenberg, S. J., Flores, M. F., Martinez, S., Hernandez, C., Osorio, E., Velasco, S. R., Perroni, E. (2006). Reduced intellectual development in children with prenatal lead exposure. *Environmental Health Perspectives, 114(5),* 791-797.

Tsaih, S. W., Korrick, S., Schwartz, J., Amarasiriwardena, C., Aro, A., Sparrow, D., & Hu, H. (2004). Lead, diabetes, hypertension, and renal function: the normative aging study. *Environmental Health Perspectives, 112 (11),* 1178-1182.

U.S. Environmental Protection Agency (USEPA). 1994. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Publication Number 9285.7-15-1. EPA/540/R-93/081.

U.S. Environmental Protection Agency (USEPA). 2001. Lead; Identification of Dangerous Levels of Lead; Final Rule. Federal Register. Vol. 66 (4): 1206-1241.

Zahran, S., Mielke, H. W., Weiler, S., Berry, K. J., & Gonzales, C. (2009). Children's blood lead and standardized test performance response as indicators of neurotoxicity in metropolitan New Orleans elementary schools. *Neurotoxicology, 30 (6),* 888-897.